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CODE OF PRACTICE FOR SUBSURFACE INVESTIGATION FOR POWER HOUSE SITES

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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CODE OF PRACTICE FOR SUBSURFACE INVESTIGATION FOR POWER HOUSE SITES

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(*Continued on page* 2)

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AMENDMENT NO. 1 AUGUST 1998
TO
IS 10060 : 1981 CODE OF PRACTICE FOR SUBSURFACE INVESTIGATION FOR POWER HOUSE SITES

[*Page* 5, *clause* **2.3.1**(a)] — Substitute 'exists' *for* 'exit'.

[*Page* 6, *clause* **2.3.2**(e), *line* 2] — Substitute 'fluvioglacial' *for* 'fluroglacial'.

[*Page* 8, *clause* **3.1.3**(a)] — Substitute 'Permafrost' *for* 'Permofrost'.

[*Page* 9, *clause* **3.2.1**(d)] — Insert 'of' between 'depth' and 'water'.

[*Page* 10, *clause* **3.3.3**(b), *line* 5] — Substitute 'electrical' *for* 'electric'.

[*Page* 11, *clause* **4.1.3.2**, *line* 2] — Substitute 'cavity' *for* 'cavyit'.

[*Page* 13, *clause* **4.3.2**, *line* 6] — Substitute 'Poisson's' *for* 'Poission's'.

(RVD 05)

Reprography Unit, BIS, New Delhi, India

Indian Standard

CODE OF PRACTICE FOR SUBSURFACE INVESTIGATION FOR POWER HOUSE SITES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 31 December 1981, after the draft finalized by the Subsurface Exploration Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 With the increasing demand for power in the country, an increasingly large number of power houses (hydroelectric, thermal, and nuclear) are being built. One of the major requirements in planning, design and construction of these power houses is proper and adequate subsurface investigation. The object of subsurface and related site investigation is to provide the engineer with as much information as possible about the existing conditions, for example, the thickness of overburden and other geological features of the area. This code has been prepared to serve as a guide in such investigations.

0.2.1 The methods of subsurface investigation enable vertical sections of the strata to be drawn based on *in-situ* tests, samples tested for determining characteristics such as shear strength parameters, bearing capacity of the soil, permeability, water table, and soil or rock type classification. This information together with the normal topographical survey provides the engineer with complete details of the site and enables him to prepare economical designs for the power house structures.

0.3 In the formulation of this standard, due weightage has been given to co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS . 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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*Rules for rounding off numerical values (*revised*)

1. SCOPE

1.1 This standard gives guidance on the type, extent and details of subsurface exploration needed in connection with power houses of the following types:

a) Hydroelectric power houses :

   i) Surface power houses, and
   ii) Underground power houses;

b) Thermal power houses, and

c) Nuclear power houses.

1.1.1 This standard provides guidelines for planning the exploratory work, through various stages of the project development. These recommendations may have to be modified for individual projects, depending upon the site conditions and other conditions peculiar to each project, such as height and importance of the power house and the heterogeneity of foundation formations.

1.2 The term subsurface exploration, as used herein, covers all types of exploration connected with determination of the nature and extent of soil at or near the power house site.

1.3 This code does not, however, cover the types and methods of exploration for materials of construction for power houses such as soil and rock and material for riprap.

2. GENERAL

2.1 In the design of some components of power house structure foundations, special attention is given to the effect of vibrations and sensitivity to settlements. Hence, the results of subsurface exploration should provide enough data for the study of these features and exploration should be very detailed and thorough Faults, shear zones, weathered horizon and joints found in the rock mass constituting the foundation shall be demarcated. All changes in rock type and formation contacts shall be studied in detail.

2.2 The type and extent of exploration shall be commensurate with the size and importance of the project and will depend upon the size of the power house and the type of foundation.

2.3 Subsurface explorations in connection with a power house shall cover a specified area around the power house site and shall be carried out to a specified depth. Depending upon the type of power house, investigation shall be required for the following areas of the power house complex:

a) Forebay,
b) Penstocks,
c) Locations of turbine and generators,
d) Afterbay,
e) Switch and transformer yards,
f) Foundations of high stacks (chimneys),
g) Area of boilers,
h) Nuclear reactors and ancillaries, and
j) Other power house components.

2.3.1 A complete programme of exploration shall be able to give information regarding the following points:

a) Types of different soil and rock masses that exit in the foundation and abutments;

b) The location, sequence, thickness and aerial extent of each soil/rock stratum, including a description and classification of the soils, their mineral and chemical constituents and their structure, stratification in the undisturbed state, significant geological or other structural features, such as buried channels, seams, joints and fissures,

c) The depth and type of bedrock as well as the location, sequence, thickness, areal extent, altitude, depth of weathering, soundness, and description of rock in each rock stratum within the depth of exploration;

d) The characteristics of the ground water, including whether the water table is perched or normal, influent or affluent, direction of flow of ground water, depth of and pressure in artesian zones and chemical quality of ground water; and

e) Engineering properties of the overburden and rocks.

2.3.2 *Exploration shall also be needed for study of the following problems:*

a) Determination of stability of slope adjacent to plant excavation;

b) Determination of the stability and erosion characteristics of the tail race channel (to know if lining is required),

c) In the case of thermal stations, if water is to be obtained from wells, subsurface studies directed to location of wells and their design, and the effects of suction and depletion of subsoil water level in the power house structure foundations (*see* Note);

Note — Possibility of sulphuric acid and sulphates formed by the percolation of water through ash dumps of thermal plants using coal reaching the foundations and their impact, such as attack on concrete/steel or leaching of certain salts causing foundation settlement may also be examined

d) In hydroelectric power houses the effect of seepage water on subsurface material;

e) *Landslides, Rockfalls and Avalanches* — The stability of glacial and fluroglacial material with thin soil cap, creep of soil covered hill slopes, etc, shall be studied In the case of power houses placed at the foot of a hill or on a steep hillside, the hill slope shall be examined for existing or potential landslides or rockfalls. The location of power houses in high altitude areas shall take into account the possibility of avalanches affecting the stability of the power houses; and

f) In the case of nuclear power houses located on seashore, shoreline stability may be assessed.

2.4 For soils, test in accordance with IS : 2131-1963* and **4.3**, **4.4** and **12.2** of IS 6955-1973† may be conducted at the required locations.

2.4.1 Wherever drilling in rock is resorted to, NX or larger size would be preferably used as large diameter cores would be useful for studying joint patterns and fracturing (*see* IS : 6926-1973‡). As loads are heavy, shear tests on rock samples may be necessary.

2.5 For general principles and procedures to be followed for investigation and sampling, reference may be made to IS · 1892-1979§. For exploration by pits, trenches, boring, drifts and shafts, references may be made to **7** to **11** of IS : 6955-1973†.

2.6 The extent of foundation exploration required for power houses of given size varies from site to site, depending on the subsurface conditions, and cannot be adequately visualized in advance The exploration generally proceeds in stages, the details of each stage growing out of the one before It normally follows a learn-as-you-go procedure in which characteristics of the subsurface soils and conditions are developed in progressively greater detail as the exploration proceeds.

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*Method for standard penetration test for soils

†Code of practice for subsurface exploration for earth and rockfill dams

‡Code of practice for diamond core drilling for site investigation for river valley projects

§Code of practice for subsurface investigations for foundations (*first revision*)

2.7 The subsurface exploration required for a power house are grouped under the following stages:

a) Reconnaissance stage investigations;
b) Preliminary stage investigations;
c) Detailed or pre-design stage investigations; and
d) Construction stage investigation

2.7.1 The type of investigations required for the last 3 stages will be the same; only difference being in the details of information gathered, quantatively. Therefore, after describing the reconnaissance stage investigations, the type of information required for the last 3 stages are described together and then the quantitative detail of information for all the 3 stages. If it is found that the properties of foundation material vary too much, then, in each bay, information shall be gathered at least at 3 points.

2.8 Type of Information Required

2.8.1 *Settlement*

2.8.1.1 For finding out the safety of the power house, in so far as uniform and equal settlement are concerned, the following investigations shall be carried out:

a) A chart showing the strata below final foundation level up to one-and-a-half times the width of the substructure of the power house housing the main generating equipment shall be prepared. Investigations shall be carried out to find out if there are compressible clay or other objectionable layers within this depth. In rock with adequate bearing characteristics the bore holes need to penetrate only about 8 m. For the purpose of investigation, unless otherwise known, it may be assumed that the foundation of hydroelectric plants generally are 9 to 12 m below the original ground surface.

b) The safe bearing pressure at the foundation level of the power station shall be found out in (i) dry, (ii) normal, and (iii) submerged soil conditions

2.8.1.2 In order to predict any settlement, modulus of the foundation soil, that is, intensity of soil pressure divided by the settlement shall be found for all different materials met with in the substrata up to depths indicated in **2.8.1.1**. This modulus shall be found for dry, normal and submerged conditions of the strata

2.8.2 *Sliding* — For the stability of the power house it is important to see that the horizontal forces acting above any plane and tending to slide the structure along that plane are not greater than the resisting forces of friction or the shear strength of the materials of foundations forming the plane.

2.8.3 *Ground Water Conditions* — In order to find the extent of submergence of the soil, high and low spring levels at the site of the power house shall be recorded

2.8.4 *Dynamic Stability* — For the determination of dynamic stability, dynamic properties of the soil shall be determined in accordance with IS : 5249-1977* and also to the requirements of IS : 1893-1975†.

2.8.5 Any other characteristics required by the field or design engineer for a particular locality shall also be determined.

3. HYDROELECTRIC SURFACE POWER HOUSES

3.1 Reconnaissance Stage Investigations

3.1.1 The scope of investigation during this stage is confined to the investigation of the suitability of constructing a surface hydel power house in the area where the required drop is available to create head for generation of electricity The investigation with the general reconnaissance of the area shall be done on 1 · 50 000 scale topo-maps having contour interval of 20 m, so as to establish broad topographical and geological features of the foundation material.

3.1.2 In case the site is near hilly slopes, stability of the hill slopes shall be investigated. In sites subject to avalanches, the direction of avalanche routes and the magnitude of avalanches shall be studied.

3.1.3 In case of sites at high altitude, investigation shall clearly bear out the suitability of foundation material with particular reference to the following conditions:

a) Permofrost, and

b) Stability of glacial and diluroglacial material with a thin soil cap.

3.1.4 The presence and extent of artesian pressures below the foundation material shall be investigated to determine whether the site is suitable for power house location or not.

3.2 Preliminary Stage Investigations

3.2.1 *Objectives and Types and Methods of Exploration* — During this stage data for formulation of the project are collected. The coverage of exploration

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*Method of test for determination of dynamic properties of soil (*first revision*)

†Criteria for earthquake resistant design of structures (*third revision*)

shall be adequate for examination of the feasibility which includes estimation of the cost and evaluation of the benefits. This stage also includes studies for preliminary choice of the alignment as well as the height of the power house. This stage of exploration includes the following.

a) Exploration by test pits, trenches, drifts and shafts;

b) Exploration by geophysical methods,

c) Exploration by drilling using coring and non-coring methods or by other boring methods,

d) Determination of the depth water table and evaluation of field permeability; observation of temperature, pressure and discharge of springs not at the surface or in exploratory borings, trenches, etc;

e) Field penetration and field density test in overburden; and

f) Laboratory tests on representative samples and undisturbed samples for the determination of engineering properties of the overburden material.

3.2.2 In order to fix the preliminary dimensions of the power station and its general lay-out it will be necessary to give the information required in **3.4**

3.2.3 After locating the most suitable site from the results of reconnaissance stage investigation, information specified in **2.8** shall be found out for one point only situated at the middle of possible power house layout.

3.2.4 In case of location in alluvium soil, investigation shall bring out presence, if any, of layers of silt, peat, quick sand or a high content of clay which might cause foundation problems.

3.3 Detailed (Pre-construction) Investigation Stage

3.3.1 These investigations are required for obtaining data required for detailed design of all structures related to the power house. These investigations shall be conducted at the final location of the power house and appurtenant works fixed from preliminary stage investigations.

3.3.2 In this stage of investigation, all data required for detailed design and preparation of construction drawings shall be collected. Close co-ordination is essential between the work of the organizations for exploration, geological work and design.

3.3.3 Investigations at this stage shall comprise the following:

a) Intensive exploration by additional drilling and pitting (trenches and shafts where found necessary) of the foundation to determine spatial distribution and characteristics of different types of foundation materials in relation to specific design features;

b) Use of geophysical methods to define in greater detail the subsurface conditions, such as the depth to bed rock or depth to water table in specific sections of the power house base. During this stage, use of borehole geophysical methods, such as electric logging, as and when required, may be found advantageous to define particular characteristics of overburden and bed rock,

c) Defining of geohydrological characteristics of the foundations and their environments through pumping in or pumping out tests as dictated by site conditions;

d) Ascertaining the groutability of foundations through trial grouting of specified reaches; and

e) Special field tests like blasting tests (to determine whether the material is liable to liquefy under seismic disturbance) and field shear tests wherever found necessary

3.3.4 Information specified in **3.4** may be obtained for at least one point situated at the middle of the unit bay, erection bay and control bay. More boreholes may be required, depending upon the geological conditions.

3.4 Construction Stage — Construction stage exploration shall aim at making available data generally for the evaluation of specific foundation preparation and treatment. In case, after actual excavation, it is found that the properties of foundation material vary too much, then, in each bay, information shall be gathered at least at 3 points. A complete record of the foundation features shall be maintained at this stage. This is essential for the solution of post construction problems, if any.

4. HYDROELECTRIC UNDERGROUND POWER HOUSES

4.1 Reconnaissance Stage Investigations

4.1.1 The scope of investigations during this stage is confined to the selection of the most suitable sites from the geological considerations, besides satisfying the engineering requirements The investigation shall proceed with the general reconnaissance of the area on 1 : 50 000 scale topo-maps having contour of 20 m to establish broad geomorophological features. Lithological characters and altitude of the host rock and its major jointing, shear zone and pattern, and the major structural and tectonic features, such as folds, faults and thrusts, shall be recorded and their significance in terms of the seismicity of the area shall be evaluated After eliminating obviously unsatisfactory sites, reconnaissance stage explorations shall be done to establish the nature and extent of overburden cover and major active or potential slide features along the slope. Preferably, thinly bedded fissile and highly fractured rocks shall be avoided and slope configuration shall be studied with reference to stability and availability of sound rock cover over the cavity A programme of surface and subsurface investigations shall be chalked out for the selected site to establish the depth of open and slump joints or potential slide mass as well as depth to sound rock over the proposed cavity. The reconnaissance stage investigations shall include those indicated in **4.1.2, 4.1.3** and **4.1.4.**

4.1.2 *Surveys*

4.1.2.1 Topographic survey on 1 : 1 000 scale shall be carried out, extending from the head race tunnel end to the tail race tunnel end and covering the hill slope for 150 m on either side of the proposed sites of the power house structure and penstocks. This shall be used as a base map for detailed geological mapping in the preliminary stage of investigation to demarcate significant geological and structural features of the area

4.1.2.2 Topographic sections shall be taken on 1 : 1 000 scale at approximately 30 m interval covering the entire area noted in **4.1.2.1.** The geology of the area shall be plotted along these sections and projected to the power house grade to develop forecast sections for further geotechnical evaluation.

4.1.3 *Subsurface Exploration*

4.1.3.1 *Drifts* — A minimum of one drift for each alternative shall be excavated normal to general trend of contours towards the power house location to explore the extent of relief or slump jointing and depth to sound rock, nature and spacing of prominent joints, fractures and shear zones, at and around the power house cavity. This drift will also help in providing data on ground water conditions. The drift shall preferably be 2·2 m × 1·5 m in sections and wherever possible it shall be located near the proposed haunch elevation of the power house cavity. A few cross cuts may also become necessary for exploration of specific features.

4.1.3.2 *Diamond core drilling* — Selected drilling, wherever feasible, for one or 2 holes may be required to demarcate rock cover over the cavyit and lithologic continuity of the rock units harbouring the power house cavity and to explore the existence of solution cavities, if any. Each hole shall be drilled down to the base of the proposed power house unit and water permeability tests shall be performed in its entire length in stages which shall normally be restricted to 3 m [*see* IS : 5529 (Part I)-1969* and IS : 5529 (Part II)-1973†]. Water bearing conditions shall also be observed in the entire section of the hole.

4.2 Preliminary Stage Investigations

4.2.1 Here the object of investigations is to select the most suitable site for a power house based on the interpretations of surface and subsurface exploration data, comparative and subsurface exploration data, and comparative evaluation of the various alternatives. Detailed geological mapping shall be carried out concurrently with the recommended subsurface explorations and at least the following features shall be recorded:

a) Surface geological mapping shall establish:

  i) Various lithological units present in the area, their altitudes and continuity, susceptibility to weathering, geometry of the structural weak planes such as joints, nature of filling of the planes of discontinuity, slip planes, shear zones, folds and faults;
  ii) Demarcation of covered area with remarks on the nature of the material, creep and slide features;
  iii) Ground water conditions;
  iv) Existence and nature of springs - hot or cold; and
  v) Pressure of any oil or gas shows.

b) The observations in the exploratory tunnel should include:

  i) Lithologic characters of the various rock units;
  ii) Their amenability to tunnelling,
  iii) Limit of slump joints or glide cracks,
  iv) Depth to sound rock;
  v) Nature, spacing and continuity of prominent joints, slip planes, minor and major shear zones; and
  vi) Study of stress field.

c) Collection of core samples of various rock types for determination of elastic and engineering properties in the laboratory.

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*Code of practice for *in-situ* permeability tests : Part I Tests in overburden.
†Code of practice for *in-situ* permeability test : Part II Tests in bedrock

4.2.2 Based on the results of subsurface explorations, suitable recommendations regarding the location and orientation of the power house cavity shall be made. A programme of subsurface exploration by drift extending up to the tentative power house location shall be made in order to have a detailed assessment of the geological discontinuities present at the power house site. The drift shall preferably run along the long axis of the power house having at least 3 cross cuts on either side of the power house axis and extending up to the power house walls. The drifts may preferably be kept at haunch level of the roof arch. If these studies indicate the presence of adverse geological discontinuities with reference to the long axis of the power house, the orientation of the cavity shall be suitably modified. In general, it is undesirable to have prominent geological discontinuities parallel or nearly parallel to the long axis of the power house or along high walls and rock cuts.

4.3 Detailed and Pre-design Stage Investigations

4.3.1 The object of the investigation is to provide a fairly clear picture of the existing geological conditions likely to be present at the power house cavity for design of the cavity and outline of the excavation programme and treatment.

4.3.2 Critical geological observations shall be made in the exploratory tunnels made in the cavity area and the drill holes drilled earlier. Rock mechanics studies regarding geological discontinuities shall be correlated with surface observations and drill hole data. Suitable number of tests shall be performed for the determination of *in-situ* modulus of elasticity, Poission's ratio and determination of stress field in various directions, (*see* IS : 7292-1974* and IS : 7317-1974†) and also the properties of important shear zone materials and joint fillings.

4.3.3 Investigations shall cover an area around the cavity of 3 to 5 times its larger dimension, depending upon the geological complexities deciphered in the preliminary investigation stage

4.4 Construction Stage Investigations

4.4.1 The object of construction stage investigation is to explore and systematically record in 3 dimensions the geological features and related problems met with which are not revealed during the pre-design stage explorations or were revealed during the pre-design stage and their explorations were deferred for the construction stage. Such explorations shall be done according to the day-to-day requirements of the projects. A complete record of the foundation features shall be maintained at this stage This is essential for the solution of post-construction problems, if any.

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*Code of practice for *in-situ* determination of rock properties by flat jack.

†Code of practice for uniaxial jacking test for deformation modulus of rock

5. THERMAL POWER STATIONS

5.1 Investigations for thermal power houses shall generally be on the lines suggested for hydroelectric surface power houses (*see* **3**) and shall cover points appropriate to this type [*see also* **2.3.2**(c)]. For general principles and procedures to be followed for investigation and sampling, reference may be made to IS : 1892-1979*.

6. NUCLEAR POWER HOUSES

6.1 Reconnaissance Stage

6.1.1 In this stage, the most suitable sites are reconnoitered from geological, engineering and environmental considerations. Prior to field visits it is preferable to study the area with the help of aerial photographs,in the scale of either 1 : 60 000 or 1 : 25 000, to mark out the lithological units, geomophological features, like old slide debris, and tectonic features including lineament trends of the area. The last mentioned study shall be done with an objective of obtaining evidences for and against recent activity along faults. These studies shall also be directed towards geohydrological characteristics of the area. Limited ground checks are called for after a detailed photogeological assessment of the area. At this stage itself, to select alternative sites for further surveys and exploration, data on the seismic status of the area within a radius of 100 km of the site shall be collected and analysed. Wherever study of existing 1 : 2 000 000 tectonic maps indicate the existence of seismogenic features, the area of photo coverage may be extended to a radius of 300 km. A mobile seismic instrumentation unit to record micro-earthquake may be required in case seismogenic features are suspected within the area studied as above.

6.1.2 Topographic survey maps in 1 : 25 000 or 1 : 15 000 scale shall be used as base maps for geological mapping during the reconnaissance stage. Spring levels and general ground water table conditions existing in the area shall also be assessed.

6.2 Preliminary Stage

6.2.1 *Surveys* — The object of the investigation is to carry out detailed geological mapping in 1 : 1 000 scale with a view to portraying the features of the promising alternative sites. This geological mapping shall aim to establish the following:

a) The various lithological units present in the area, their altitude and continuity with a view to establish bands of sufficient width of hard and homogeneous material suitable for founding the heavy units of the power house.

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*Code of practice for subsurface investigations for foundations (*first revision*).

b) The validity of the faults interpreted from photogeologic studies, and if proved, their status of activity on field evidences shall be collected and plotted. In addition similar studies of faults, interpreted from field mapping which were not picked up by photogeological studies, shall also be carried out.

6.2.2 *Subsurface Exploration* — In areas covered by debris or terrace gravels, geophysical surveys can be considered for evaluating depth and nature of bedrock along with level of ground water table. A few diamond drill holes, preferably of NX or larger size, shall be drilled for establishing bedrock and for obtaining the cores for determining physical properties like compressive strength and modulus of elasticity by laboratory tests both under dry and wet conditions (after 72 hours of soaking in water). In such drill holes, the water table if encountered, shall be carefully, recorded and, in addition, cyclic water percolation tests shall be performed for determining the permeability of the foundation material It is essential that drilling be done for a depth of 10 m into fresh rock and during drilling double core barrel utilising bottom discharge bits shall be used. In case of alluvial formations, wash borings, auger holes, penetration tests, etc, shall be done to assess the nature of the sub-soil material and also to obtain undisturbed samples for the determination of soil properties.

6.2.2.1 In case of sandy alluvial foundation strata, geophysical blast test shall be done to determine whether the material is liable to liquefy under seismic disturbances.

6.2.3 *Geohydrological Surveys* — Date-wise data on the occurrence of springs and water table in dug wells or tube wells of the area shall be collected. The repeat measurements of these shall be done before and after the monsoon season and water table maps prepared. Data on aquifer characteristics shall be collected and depth to water table maps prepared. The chemical quality of the ground water shall also be determined.

6.3 Pre-construction State — Layout of the structure *vis-a-vis* the geology having been generally fixed, further exploration shall be carried out by coring holes drilled at the corners and grade, for determining the nature of the actual foundation material and its physical characteristics, including *in-situ* permeability. The site of the lighter structures shall also be investigated by a few drill holes or trial pits. In addition, *in-situ* load bearing tests may be conducted in overburden, alluvial and soft rock foundation to evaluate precisely the deformation characteristics. From these data, detailed geological sections for use in the final design of the structure shall be prepared.

6.4 Construction Stage

6.4.1 Depending upon the design and engineering requirements of day-to-day work, explorations and recording of geological features and related problems, revealed during the pre-construction or construction stage shall be carried out to guide the treatment of weak zones encountered during excavation of the foundation. A complete record of the foundation features shall be maintained at this stage. This is essential for the solution of the post-construction problems, if any The foundation grade geotechnical maps shall be prepared in 1 : 100 scale, giving details of the major/minor rock structures, lithological variations, nature and abundance of the planes of discontinuities with their spatial distribution and nature of infilling material, if any, and water table conditions.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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Printed at Manipal Power Press, Manipal, India